1.0 EXECUTIVE SUMMARY

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1.1 Purpose

The purpose of this report was to evaluate and quantify the non-fishing human induced mortality on fisheries resources in Galveston Bay. The specific objectives of the study were: (1) to collect and summarize existing information regarding authorized water intake structures in Galveston Bay; (2) to collect and summarize existing information regarding impacts to estuarine species from other non-fishing human activities such as dredge and fill operations, seismic exploration, pipeline construction and removal, and oil and gas exploration/production activities; (3) to quantify the magnitude of mortality to species by major taxa, size ranges, seasons, and areas within the Galveston Bay system; and (4) to present any implications of mortality patterns as they affect fisheries population dynamics in Galveston Bay.

1.2 Methods

The approach used by Jones and Neuse, Inc. (JN) consisted of a comprehensive review of literature and existing data on fish mortality caused by human activity other than fishing. This was accomplished by accessing information available from the Galveston Bay Information Center, Texas A&M University - Galveston, other data bases (e.g. UTCAT, DIALOG, Scisearch, Biosis Previews, Oceanic Abstracts, Pollution Abstracts, Water Resources Abstracts), on-going projects, as well as compiling published and non-published data from federal, state, and local entities. Data base searches focused on information specifically from Galveston Bay. These data bases were evaluated for information on a variety of causes of fish mortality including impingement and entrainment, dredge and fill operations, seismic exploration, pipeline construction and removal, and oil and gas exploration/production activities.

JN also sent questionnaires to permitted water rights users that withdrew water directly from segments within the study area and withheld water for uses that would have the greatest probability of impinging or entraining estuarine organisms. The purpose of this questionnaire was to determine: (1) whether the permit was currently used; (2) the frequency and time of year of the diversion; (3) the quantity of water diverted; (4) the purpose of the diversion; (5) the intake rate and velocity; (6) methods used to divert fish from the intake; and (7) whether the user had conducted any impingement and entrainment studies at their facility.

JN contacted Houston Lighting and Power (HL&P) to obtain all impingement and entrainment studies conducted at HL&P generating stations on Galveston Bay to determine the most frequently impinged or entrained species. The length, weight, and peak impingement periods for the most frequently impinged and commercially/recreationally important species were also identified. Other information obtained included injury rates, percent survival after impingement and entrainment, including the delayed effects of impingement and entrainment, and the effects of elevated temperatures in discharge canal waters for species of concern. Data were available for the following HL&P generating stations: P.H. Robinson (Landry 1971 and 1977, Chase 1977, McAden 1977, Chase 1978, and Greene et al. 1980a), Webster (Greene et al. 1980b), Sam Bertron (Greene et al. 1979), Deepwater (Greene 1980), and Cedar Bayou (Jobe et al. 1980 and Southwest Research Institute, unpublished data).

Several federal, state, and local agencies were contacted to obtain fish kill records. These agencies included the U.S. Environmental Protection Agency (EPA)-Region VI, the Texas Parks and Wildlife Department (TPWD), the Texas Water Commission (TWC), the Harris County Pollution Control Department (HCPCD), and the Galveston County Health District. JN requested records only from the TPWD and the TWC because they had the most complete and comprehensive data bases. In addition, all the other agencies reported fish kills to the TPWD or the TWC. However, several records were obtained from the HCPCD. Reports used during the development of this study were limited to those which occurred in the defined study area, contained the numbers of fish killed, and were caused by human activity. Data were quantified by causes, species, size ranges, magnitude, and spatial and temporal characteristics.

According to TPWD Coastal Fisheries staff, there is no sure way to assess the standing crop of fish populations in Galveston Bay with any degree of certainty. Therefore, relative abundance is assumed to be a good indicator of the standing crop status. Loeffler and Walton (1992) evaluated the status of fisheries populations in Galveston Bay by analyzing trends in catch per unit effort for 14 species from 1963 to 1968 (National Marine Fisheries Service data) and from 1975 to 1990 (TPWD data). This study was briefly summarized as it related to the overall status of fisheries populations in Galveston Bay.

1.3 Results

While several data bases were searched, only the Galveston Bay Information Center at Texas A&M-Galveston provided information directly applicable to this report. In addition, there was a great deal of information available addressing the effects of cooling water operations (e.g., impingement, entrainment, and elevated temperatures) on finfish and shellfish in Galveston Bay. By far, the majority of information came from studies conducted at five HL&P generating stations (Robinson, Webster, Bertron, Deepwater, and Cedar Bayou) located within the Galveston Bay system. Those facilities that had the highest pumping rates impinged the most organisms. The highest species diversities were observed at facilities with the greatest sampling frequency and pumping rates. However, it is likely that other factors such as intake velocity, species life history and distribution patterns, and quality and availability of habitat also affected species diversity. A review of TWC permitted water rights users withdrawing water from Galveston Bay revealed that only one other facility, a chemical plant in Texas City, could have a major impact on finfish and shellfish in the bay. However, no impingement and entrainment studies have been conducted at this facility.

The species most frequently affected by cooling water operations coincided with those that are probably most abundant in the bays. These species included white shrimp (*Penaeus setiferus*), brown shrimp (*Penaeus aztecus*), blue crab (*Callinectes sapidus*), Gulf menhaden (*Brevoortia patronus*), bay anchovy (*Anchoa mitchilli*), sand seatrout (*Cynoscion arenarius*), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). Species less frequently impinged at all stations but still in large numbers included sea catfish (*Arius felis*), striped mullet (*Mugil cephalus*), Atlantic cutlassfish (*Trichiurus lepturus*), and least puffer (*Sphoeroides parvus*). Commercially and recreationally important species such as spotted seatrout (*Cynoscion nebulosus*), black drum (*Pogonias cromis*), red drum (*Sciaenops ocellata*), and southern flounder (*Paralichthys lethostigma*) were infrequently impinged and only in small numbers.

Organisms impinged or entrained were generally post larval crustaceans and juvenile fishes that could not swim faster than the intake velocities at the generating stations. Larval fishes and fish eggs were also entrained at these facilities. The most abundant larval fishes included naked gobies (*Gobiosoma bosci*), Gulf menhaden, bay anchovy, and comb-tooth blennies (family Blenniidae). The sizes most frequently impinged varied by station. The numbers of organisms impinged usually coincided with the life history of the organism.

Calculated overall probabilities of survival, including the immediate and delayed effects of impingement and entrainment but excluding the effects of elevated temperatures in the discharge canal, have been calculated for the HL&P Robinson station. Crustaceans (brown shrimp and blue crab) had overall probabilities of survival greater than 0.70 (greater than 0.45 for white shrimp) at Units 1 and 2. Overall probabilities of survival were lower at Units 3 and 4 (i.e., greater than 0.30 for white and brown shrimp and greater than 0.50 for blue crab). Overall probabilities of survival for fish were much lower than for crustaceans. Most fish had survival probabilities less than 0.10; however, spot had survival probabilities of 0.25 at Units 1 and 2 and 0.04 at Units 3 and 4. Units 3 and 4 had greater pumping rates than Units 1 and 2.

The effects of elevated temperatures were noticed at 30 C for Gulf menhaden. Atlantic croaker were repelled from the Robinson discharge canal at 32 C. Bay anchovy, sea catfish, sand seatrout, and spot avoided temperatures greater than 35 C. Decreased survival for larval blennies was observed at the Robinson station when water temperatures reached 36.7 C with no individuals collected in the discharge canal when temperatures exceeded 38.4 C. At the Cedar Bayou station, blue crab survival decreased when discharge canal water temperatures exceeded 33.3 C with no survival when temperatures were greater than 36 C. No brown shrimp or white shrimp survived when discharge canal water temperatures were greater than 33.3 C at Cedar Bayou. At the Robinson station, fish egg survival ranged from 11.3% to 54.3% when discharge canal temperatures ranged from 38.4 C to 38.9 C. However, no fish eggs were found alive in cooling towers when temperatures ranged from 32.2 C to 34.7 C, indicating fish eggs were more sensitive to physical impacts from bouncing and splashing in the towers.

There were some beneficial effects noted from the discharge of heated effluent. During the late winter and early spring, rapid growth of young-of-the-year spot was observed in the Robinson canal. Also, large numbers of fish were found congregated in the canal and near the outfall during the winter months.

Over 87 million organisms weighing more than 447,000 kg were estimated to be impinged during one year (1978) when data were available for all five HL&P stations on Galveston Bay. During this year, the most organisms estimated impinged occurred at the Cedar Bayou station, followed by the Robinson station. Similar numbers of organisms were estimated impinged at the Bertron and Webster stations. The fewest numbers were estimated impinged at the Deepwater station. However, the annual estimates for the total number and weight of organisms impinged at the Cedar Bayou station (the only station for which more than two years of data were collected) showed an overall decreasing trend from 1974 to 1980.

In addition, the results of survival studies indicated that only a portion of impinged organisms would die. Organisms were exposed to temperatures exceeding thermal tolerances (beginning at 30 C for menhaden) only from May through August which corresponded to the time when fewer organisms were impinged. Therefore, survival rates were greater during the time period when more organisms were impinged. More crustaceans were impinged by number and weight than finfish other than menhaden. Survival studies demonstrated that crustaceans (white shrimp, brown shrimp, and blue crab) generally had higher survival rates than finfish at HL&P stations. Therefore, the organisms most frequently impinged had higher survival rates. It should be noted that impingement results do not include the estimated number of organisms impinged from the only other facility identified that could possibly impinge the magnitude of organisms as the HL&P facilities.

Loeffler and Walton (1992) analyzed catch per unit effort (CPUE) trends of 14 species in Galveston Bay using National Marine Fisheries Service data from 1963 to 1968 and TPWD data from 1975 to 1990. Of these 14 species, only blue crab and white shrimp showed declining trends in CPUE. Despite these results, Loeffler and Walton (1992) concluded that Galveston Bay was still a very viable ecosystem. The size classes of blue crabs showing a declining trend were similar to size classes impinged at HL&P facilities. The most critical size classes for white shrimp were impinged most frequently at the Robinson and Deepwater facilities. Unfortunately, no overall impingement trend data were available for HL&P facilities to compare to the CPUE trend study. However, more than 50% of blue crab and white shrimp estimated impinged at HL&P facilities during 1978 were impinged at the Cedar Bayou station, and there were eight years of impingement data collected at this station. While no size ranges were reported for crustaceans at the Cedar Bayou station, no obvious trends were observed for blue crab impingement and a decreasing trend was observed in the number of white shrimp impinged from 1975 to 1980.

The fish kill reports used in this study (20 years of TWC and 13 years of TPWD records) were limited to those which occurred in the defined study area, contained the number of fish killed, and were caused by human activity. Of the 321 identified reports, 220 met these criteria. An estimated 175.2 million finfish and shellfish were killed in these 220 fish kills.

The causes of 121 fish kills involving 156 million finfish and shellfish were unknown. The remainder of incidents reported and fish killed were attributed to point sources (approximately 2.4 million fish killed in 56 incidents) and nonpoint sources (16.3 million fish killed in 43 incidents). During this period, a decreasing trend in the number of fish kills reported and the number of fish killed was observed.

The causes of the majority of fish kills attributed to point sources were unknown spills at electric power generation facilities, sewage treatment plant by-passes, pipeline leaks and unknown spills at chemical plants, ocean dumping, and seismic exploration. With respect to nonpoint source events, 93% of the mortality and 81% of the incidents were attributed to low dissolved oxygen from undefined runoff events.

Due to the lack of data, no trends were detected regarding the species killed or their length-frequency. However, Gulf menhaden was the species most often affected. Essentially all of the fish mortality attributed to point sources occurred from May to October with peaks in May and September. Only one impingement related fish kill at an HL&P facility killing an estimated 10,000 rough fish was reported to state agencies. Nearly 11,000 fish (77% commercial or sport species) were killed in three fish kills attributed to thermal discharges from power plants. Nonpoint source related fish kills most often occurred from June through September with a peak in August. Fish kills most often occurred in tributaries to Clear Lake, East Bay, and West Bay, San Jacinto Bay, Dickinson Bayou, West Bay, and Clear Lake.

Recommendations

While non-fishing human induced fisheries mortalities can be quantified, the impact of these mortalities on overall finfish and shellfish populations remains unknown. In the absence of any known standing stock estimates for Galveston Bay, JN used the TPWD report on CPUE trends in Galveston Bay. Unfortunately, the fish kill and impingement data evaluated in this report were not directly comparable to CPUE data. As a result, impacts of non-fishing human induced mortalities of fisheries populations could only be loosely inferred. Before additional or follow-up studies are undertaken, methods should be developed by fisheries specialists to determine or estimate standing stocks. Once methods are developed to estimate fisheries standing stocks in Galveston Bay, fisheries experts can use the results of this report to recommend additional data that should be collected by fish kill investigators to evaluate impacts to fisheries populations.

While the number of fish kills reported to agencies is beyond their control, the quality of investigations and the amount of data gathered are certainly factors agencies can control. As a result, JN recommends that all agencies collecting data should use similar investigation procedures such as the American Fisheries Society fish kill investigation procedures. At the minimum, all organisms killed should be identified to species. The total number killed by inch group should also be estimated. Intensive efforts (e.g., water quality testing, fish autopsies, etc.) should be conducted for each fish kill to identify the cause of fish mortalities. Agencies should coordinate their efforts to minimize duplication of effort. In addition, agency fish kill investigation programs should be adequately funded and staffed to support these efforts. Many of these recommendations are already being used by state agencies. However, agency staff, particularly new employees, should be continually trained in these procedures.

One of the most obvious results of this study was that, for the years data were available, millions of finfish and shellfish were impinged at the five HL&P generating stations located on Galveston Bay. Only one other facility was identified that might pump the quantities of water with similar intake velocities as the HL&P power plants. While impingement data were available for at least one year at each of the facilities, entrainment data were not available for all facilities. In addition, multi-year impingement data were available for only the Cedar Bayou station. While

the impacts of impingement and entrainment to finfish and shellfish populations in Galveston Bay remain unknown, impingement and entrainment remain the single largest source of impacts identified by this study. Additional multi-year impingement and entrainment studies should be conducted at these facilities to determine how they impact finfish and shellfish populations in Galveston Bay. However, these studies should not be initiated until a study design is developed that would establish a direct cause and effect relationship between mortalities due to impingement and entrainment and its effects on finfish and shellfish populations in Galveston Bay.